Dominance and Exhibit Use in Captive African Elephants (*Loxodonta africana*)

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Dominance and Exhibit Use in Captive African Elephants (*Loxodonta africana)*

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Dedicated to Penny and Petunia, who sparked my passion for their species.

Petunia

1973 - 2016

Penny

1979 - 2017

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SUMMARY

The African elephant (*Loxodonta africana*) is a highly social species that typically lives in large, matrilineal family groups called herds which contain a linear dominance hierarchy between the adult females. Management plans for African elephants in human care try to replicate their natural social structures by creating small herds of females but these individuals typically are unrelated except in the case of mothers and their offspring. Despite low genetic relatedness, these females still create their own dominance hierarchies within the herds. Although elephants in human care have all of their needs provided for, dominance within herds can lead to preferential access to high-value resources such as food, water, and shade structures.

The purpose of this study was to observe how the two female African elephants at Zoo Atlanta, Tara and Kelly, interacted with each other in terms of their usage of their current exhibit space. An incident occurred during data collection that led to a week-long physical separation of the elephants and the results of this study were then separated into two data sets. Anecdotal evidence of Kelly being the dominant individual was confirmed by Kelly initiating all 110 observed social interactions throughout the course of the study. Tara typically showed her submissiveness by walking away from the interaction. After the incident there was a higher mean frequency of social interactions between the two elephants per hour. The amount of neutral and agonistic behaviors rose as well. It appeared that Kelly was re-establishing her dominance over Tara after their separation.

Both elephants had non-random patterns of exhibit spatial use when they were together and when they were alone in the exhibit, as well as before and after the incident. Before the incident, Kelly dominated use of the two areas that had direct access to the

indoor barn when both females were in the exhibit together while Tara used the remaining two areas more often. These elephants have a complex social history, which includes Kelly dominating use of the barn and resources after a change to their social structure. As the dominant individual, Kelly had preferential access to this putative high-value area. Kelly continued to stay in the areas closest to the barn when separated from Tara. The pattern of spatial use in the exhibit displayed by Tara when separated from Kelly was different from her pattern when they were together; Tara used the area closest to the barn when alone. The patterns after the incident were similar to those from the before results except Tara used the furthest area from the barn with a higher frequency when alone in the exhibit in addition to the closest. This change may have been caused by Tara's restricted mobility after the incident.

Before the incident all social interactions between the elephants, including agonism, occurred randomly throughout the outside portion of the exhibit despite both elephants having specific patterns in how they used the exhibit. After the incident there was a non-random pattern in the location of all social interactions. More occurred in the area closest to the barn than would be randomly expected, which matches Kelly's dominating use of that area. Although the occurrence of agonistic behaviors by area changed after the incident, the pattern was still not statistically significant.

Chapter 1. Introduction

1.1 Literature Review

1.1.1 Elephant Social Dynamics

Wild African elephants (*Loxodonta africana*) live in different social situations depending on age and sex. Adult females and their young offspring live together in matrilineal groups led by a matriarch. The matriarch typically is the oldest and largest female in a herd and leads the family across their migration routes because of her knowledge of where resources have historically been located. Female offspring will stay with their natal group when they mature but male offspring break off and form small bachelor herds or wander the savannah on their own. Adult males only come in contact with family groups when they are trying to mate (Freeman et al., 2004; Schulte, 2000; Vidya and Sukumar, 2005).

1.1.2 Territorial Behavior in Elephants

Wild herds of elephants do not express high levels of territoriality. A study by Ntumi et al. (2005) found that the home ranges of herds often overlap and can range in size from 33 km^2 to over 5000 km^2. They did, however, discover that the core of each home range where the herd spent over 50% of their time did not overlap in the groups they studied. In addition, Wittemyer and Getz (2007) determined that wild elephants create fission-fusion societies. Herds congregate into higher levels of organization if food is plentiful or when extra safety is needed but will split apart when resources become more patchily distributed or predatory threats are low. The amount of intergroup competition is reduced by splitting up into smaller groups when resources are low.

Intergroup competition does not entirely disappear though and can result in dominant groups gaining access to preferred areas where human-elephant conflict is low and resources are more abundant during the dry season (Wittemyer et al., 2007). Studies looking at intragroup dynamics in the wild have found evidence of stable, linear dominance hierarchies within herds where the more subordinate individuals and their offspring can be adversely affected by competition with fellow herd members for the best access to resources (Wittemyer et al., 2005; Wittemyer and Getz, 2007).

1.1.3 Management of Elephants in Human Care

In order to provide animals in human care with the best welfare possible, animal care facilities replicate the physical and social environments of each species' wild counterparts while eliminating challenges such as predation and finding enough resources to stay alive. For social species this includes letting the animals create their own dominance structures, only intervening in the case of injury or illness. The type of social structure a species uses can affect various aspects of welfare and management such as the male to female ratio within a group, how resources are allocated and spread throughout an exhibit, and which features should be included in exhibit design (Maple et al., 2009; Hoff et al., 1997; Ross and Lukas, 2006).

The composition of elephant herds in captivity is different from their wild counterparts because relatedness and the number of individuals per herd can be much lower than normal. As Schulte (2000) pointed out, finding a group of two or three females in the wild for an extended period of time would be highly unusual. A survey of North American zoos with African elephants found that over half kept herds of three or fewer females (Association of Zoos and Aquariums, 2018). The Association of Zoos and

Aquariums (AZA), a North American accreditation group that regulates how animals should be managed in human care, has recently changed their policy with regards to housing elephants to reflect their natural herd structures. The new standards require facilities to keep a minimum of three female elephants in a herd, along with many other policies reflecting the housing of males and multiple generations, or risk losing their accreditation (Association of Zoos and Aquariums, 2012). The lack of a genetically related matriarch plus abnormally low herd sizes in human care has encouraged research on dominance, aggressiveness, affection, and disciplinary actions by matriarchs or herd leaders to determine if captive herds are behaving like their wild counterparts (Freeman et al., 2004; Freeman et al., 2010). Although elephant herds in human care don't always contain related females, they typically maintain a similar social structure to wild herds in that they are comprised of females and their offspring and one female will usually assert herself as the leader and peacekeeper (Freeman et al., 2010). Bulls are kept in separate areas if they are housed at the same facility (Schulte, 2000).

1.1.4 Exhibit Use by Animals in Human Care

While many studies have looked at how animals in human care utilize the space and resources provided in their living quarters, most do not include an evaluation of how the dominance structure of the animals involved affects space use. An example of one that does this is an observational study (Bettinger et al., 1994) of four adult female chimpanzees (*Pan troglodytes*) at the Tulsa Zoo. Each female had a specific location that they used more often than every other female and they typically used the sections delineated in the study at different times in order to temporally avoid each other. Although this study yielded some interesting information about how the individuals

involved used the exhibit, an analysis of the dominance structure between these four females would have been helpful. Similar studies that do not consider the social relationships between the animals living together may miss the "why" behind the appearance of space use patterns.

A study that looked at how limited resources were used by individuals based on their placement in a dominance hierarchy was conducted on an American bison (*Bison bison*) herd at Jardin zoologique du Québec (Robitaille and Prescott, 1993). The dominant individuals spent more time near the barn and less time foraging than did the subordinate members of the herd. Extra feedings had to be provided to the subordinate members away from the barn and while the dominant individuals were resting in order for them to get an adequate amount of food. The authors concluded that the individuals at the top of the dominance hierarchy had preferential access to high-value food resources and resting locations (Robitaille and Prescott, 1993).

One study at Disney's Animal Kingdom investigated exhibit space-use patterns in regards to an elephant herd in human care and how the patterns of each individual was related to their place in the dominance hierarchy (Leighty et al., 2010). Five adult female African elephants (*Loxodonta africana*) had their movements within their outdoor exhibit space tracked by wearing GPS collars. Each female was assigned their dominance rank within the herd structure through a series of statistical tests quantifying various social interactions. Individuals higher up in the dominance hierarchy used a larger proportion of the exhibit and spent more time at the permanent shade structure, the watering hole, and in restricted areas on the periphery of the exhibit that had no resources. These "restricted flow areas" were also seemingly avoided by the less dominant elephants, which may have

been the result of a lack of opportunities to avoid a more dominant individual should they be in the same area at the same time (Leighty et al., 2010). This suggests that the elephants were aware of their placement within the dominance hierarchy and knew the implications in preferential access to resources that came along with it.

1.2 Purpose and Research Questions

1.2.1 Purpose of Study

The purpose of this study was to observe how the two female African elephants at Zoo Atlanta, Tara and Kelly, interacted with each other and used their exhibit space in terms of their dominance hierarchy. As previously discussed, a herd containing only two female elephants would be highly uncommon in their natural habitat. Recent changes to accreditation standards has caused many facilities to reevaluate how they can meet the new requirements but still house herds with only two individuals in the meantime. This study could be applied by other facilities that have two individuals in their herds to understand how elephants living in unusually small social groups use exhibit space in terms of their social relationships and dominance hierarchies. In addition to informing other elephant care teams of the dynamics of small herds, this study will be used in a long-term study observing the behavioral patterns of these specific elephants at Zoo Atlanta before and after they move to a new exhibit that is under construction at the time of data collection. Understanding the relationship between Tara and Kelly in their current exhibit could be used to predict how they interact with each other in a much larger space and how they may react to living with new herd members.

1.2.2 Research Questions and Hypotheses

1) Which elephant in the Zoo Atlanta is dominant?

- Hypothesis: Kelly is the dominant herd member.
- Null Hypothesis: Kelly is not the dominant herd member.

2) Do the elephants show a pattern in how they use the outdoor exhibit space?

- Hypothesis: Each elephant has a distinct pattern in how they use the exhibit space.
- Null Hypothesis: Each elephant uses the exhibit space randomly.

3) Do agonistic behaviors by the dominant individual correspond with physical location within the exhibit?

- Hypothesis: The occurrence of agonistic behaviors by the dominant individual does correspond with physical location within the exhibit.
- Null Hypothesis: The occurrence of agonistic behaviors by the dominant individual does not correspond with physical location within the exhibit.

Chapter 2. Methods

2.1 Subjects, Housing, and Management

2.1.1 Social History of Subjects and Management

The study subjects were the two female African elephants (*Loxodonta africana)* at Zoo Atlanta, Tara (ISIS# 220) and Kelly (ISIS# 227). Both individuals were orphaned in southern Africa and arrived in Atlanta in 1986 when they were 3 and 4 years old, respectively. Zoo Atlanta's management policy included chaining the elephants at night until 1989 and free contact until 2002, after which they switched to a protected contact system. "Free contact" systems allow for trainers to enter into spaces with elephants and interact with them without any physical barriers between people and animals. In previous free-contact management policies, both negative and positive forms of reinforcement were used. The current "Protected contact" system maintains a physical barrier at all times and emphasizes the uses only positive reinforcement (Brockett et al., 1999; Wilson et al., 2015).

The outdoor portion of the elephant habitat is exhibit space, approximately 790 m^2 and includes a pool, shade structure, boulders, mud holes, log piles, and slight changes in elevation. The remainder of the complex includes a barn with two rooms that can be separated, a transfer area to the barn, a separate demonstration ring between the outdoor exhibit space and the barn, and an additional demonstration ring not visible to the public (Figure 2.1). The elephants' diet consists of Bermuda hay, apples, carrots, rutabaga, celery, lettuce, and various types of browse including oak, elm, mulberry, poplar, sweet gum, among others.

2.1.2 Previous Dominance Hierarchies

These elephants have been the subjects of multiple studies in the past. From their arrival in 1986 to 2008, Kelly and Tara lived with another female elephant named Dottie who was approximately the same age (Wilson et al., 2004). Brockett et al. (1999) identified Tara as being the most dominant individual and Kelly as the most subordinate in the linear dominance hierarchy with Dottie in the middle. Later, Kelling (2008) described a circular hierarchy system where each individual had a dominant animal above them and a subordinate animal below them. Tara was dominant in respect to Dottie, Dottie was dominant in respect to Kelly, and Kelly was dominant in respect to Tara. Dottie and Tara spent a majority of their time in proximity to each other while Kelly spent more time on her own. Dottie died unexpectedly in 2008 and this event affected the relationship between Kelly and Tara (Elgart, 2015). Kelly increasingly monopolized shared food and showed aggressive behaviors towards Tara, often not allowing her to enter the barn. These behaviors were interpreted by the elephant care team to mean that Kelly was establishing herself as the new dominant individual. By the time of this study (Summer 2018), their social situation appeared to have stabilized to a state of less aggression; nevertheless, Kelly continues to display behaviors that maintain her role as the dominant female.

2.2 Materials and Methods

2.2.1 Data Collection Schedule

Data collection took place on 34 days between 3 May - 29 August 2018. Instantaneous focal sampling of one elephant occurred in 20-minute observation periods

with scans performed every 30 seconds. The first animal to be observed each day was randomized. Typically, three observation periods were done consecutively on one elephant and then three more periods were completed on the other elephant.

Zoo Atlanta is open from 09:30-17:30 hr Monday to Friday and 09:30-18:30 hr on weekends and holidays. Observations were collected between 09:30-17:30 hr, with start times being randomized. Observations were started within 15 minutes of the chosen time. The elephants' typical daily routine included two breaks during which they were temporarily brought inside the barn. During each break, one individual was brought inside the barn for an activity while the other remained in the outdoor exhibit. After the activity was over the second individual was also brought inside so that the elephant management team could go out into the exhibit to clean and put out food and enrichment. Both elephants were then let back outside. Observations were not taken in the indoor portions of the exhibit. Data points where keepers were present on the berm behind the elephant exhibit were excluded due to the fact that the behavior of the elephants often changed when their caretakers were present, either from seeking interaction with the keepers or being asked to complete certain trained behaviors.

2.2.2 ZooMonitor

The ZooMonitor mobile application software (Version 1; Ross et al., 2016) was used to collect data for this study by setting up a new program within the application. The researcher used a tablet device to collect data. The Elephant Observation program on ZooMonitor was set to record timestamps for each scan and to beep every 30 seconds to indicate the end of a scan. Before the start of each observation period the location of food items and other environmental conditions such as noise were noted. Air temperatures

were obtained from the Storm Radar: Weather Tracker app by NOAA Hurricane and Tornado Maps (iTunes App Store). Visual weather conditions were determined subjectively and classified according to Table 2.1. Data collection was cancelled in the case of heavy rain or thunderstorms.

Table 2.1: Classification of Visual Weather Conditions

Weather Category	Characteristics
Sunny	Blue skies with 0%-20% cloud cover
Mostly Sunny	Blue skies with 20%-50% cloud cover
Mostly Cloudy	50%-80% cloud cover
Cloudy	80%-100% cloud cover

The researcher recorded the locations of each individual, their proximity to one another, and which social or solitary behavior was being completed by the focal animal at each timestamp. Descriptions for all of these categories can be found in Table 2.2 and a map of the exhibit appears in Figure 2.1. The ethogram is a compilation of those used by previous researchers who completed studies on the elephants at Zoo Atlanta (Brockett et al. 1999, Wilson et al. 2006, Wilson et al. 2015). Additional comments could also be recorded for each scan if needed. Data from ZooMonitor were downloaded from the website as a Microsoft Excel document on each observation day and were compiled into one large spreadsheet over time.

Table 2.2: Ethogram of behaviors for daytime and nighttime activity budgets and stereotypic behaviors. Modified from original ethogram provided by Dr. Stephanie Braccini Slade and Dr. Megan Lee Wilson.

Solitary Behaviors	
Bite Bars	Chewing or gnawing on bars
Defecate/Urinate	Voiding of feces or urine
Drink	Ingestion of water
Feed	Manipulation and consumption of food
Head Bob	Movement of the head up and down in a repetitive motion
Lie	Lateral recumbence
Locomote	Forward or backward movement over one body length
Maintenance	Spraying mud or dust on body, scratching body with trunk, or scratching body on surface
Object Manipulation	Examination of an object with trunk, mouth, and/or tusks
Other	Any behavior not listed on the ethogram
Pace	Locomotion along the same route at least three times in a row
Stand	Upright and stationary
Sway	Standing, moving from side to side at least three times in a row
Throw/Manipulate Feces	Spraying fecal material on back, sides, belly, or tossing it in the air
Trunk Toss	Standing, but extending and withdrawing trunk at least three times in a row
Trunk Twist	Twisting the bottom portion of the trunk in a circular manner
Tusking	Digging with, or rubbing of, tusks on logs
Out of View	Subject is not within view at the time of observation

Table 2.2 (continued)

Social Behaviors	
Approach	Movement to within one body length of the recipient
Avoid	Recipient moves away while initiator is more than one body length from recipient
Charge	Approach from greater than one body length with head down
Displace	Movement of one body length from current location within three seconds of approach of another elephant
Drive	Proximate elephant places head against rump of another and pushes
Ear Flap	Ears held out perpendicular to head, oriented to another elephant, human, or change in the environment
Mount	Bipedal with front feet on another elephant
Push	Lunging at a proximate elephant from a stationary position and making contact with head and/or tusks on recipient
Sentinel	Standing proximate or in contact with another elephant that is lying down for at least five seconds
Spar	Mutual head to head contact between two elephants using tusks, trunk, or head for at least five seconds
Strike	Forceful contact of another with body, trunk, object held by trunk, or foot
Trunk to Anogenital	Contact of the trunk with the vulva or anus of another elephant
Trunk to Body	Contact of the trunk with the body or head of another elephant
Trunk to Mouth	Contact of the trunk with the mouth of another elephant
Trunk to Gland	Contact of the trunk with the temporal gland of another elephant
Trunk to Trunk	Intertwining of trunks

Table 2.2 (continued)

Proximity	
Contact	Any part of body touching another elephant
Proximate	Less than one body length from another elephant
Distant	Greater than one body length from another elephant
Separated	A physical barrier is between the two subjects
Location	
Area 1	Outdoor habitat far corner
Area 2	Outdoor habitat on the public side of the rock structure
Area 3	Outdoor habitat under shade structure
Area 4	Outdoor habitat along the pool
Area 5	Smaller outdoor habitat (demo ring)
Area 6	Large indoor area where elephants are viewed by public (barn)
Area 7	Small indoor area where elephants are not visible to public
Area 8	Outdoor paddock, transfer area from outside exhibit to barn, also contains access to Area 5
Area 9	Outdoor paddock, not visible to public

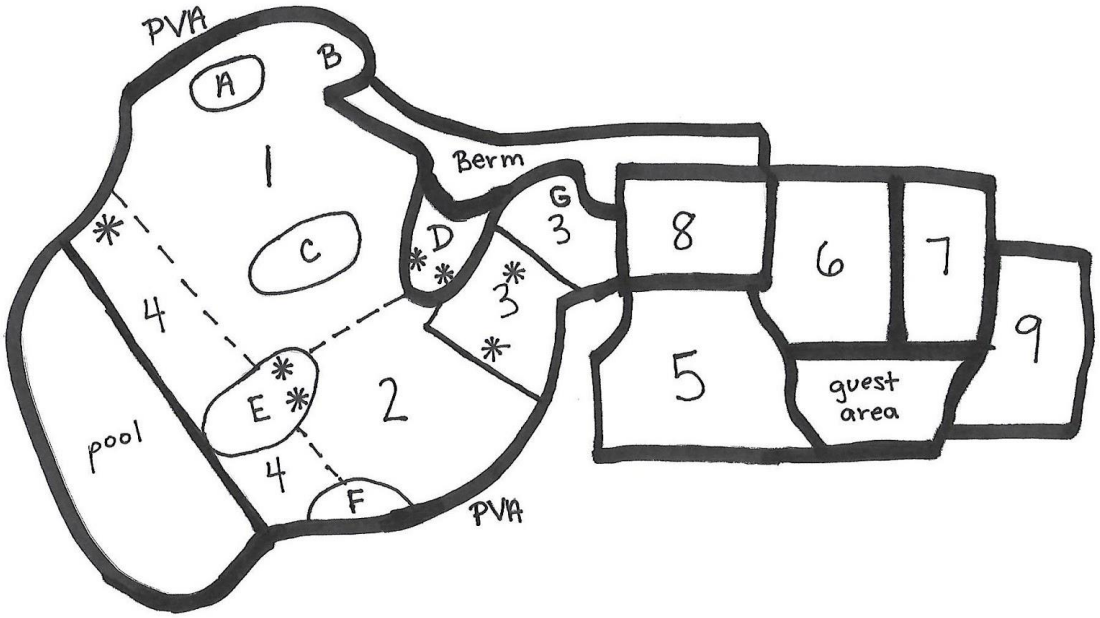

Figure 2.1: Areas of the Elephant Exhibit with Assigned Numbers. A) the mud hole; B) the corner; C) the log pile; D) the rock; E) the boulder; F) additional rocks and boulders; G) the blue water trough. PVA = Public Viewing Area - space where guests of Zoo Atlanta can get a closer view. Asterisks indicate locations of hay nets. Modified from original map provided by Dr. Megan Lee Wilson.

2.2.3 Agonistic Behaviors

Agonistic behaviors are those between individuals that involve aggression, dominance, and submission in conflict situations (Adams and Berg, 1980; Gobush and Wasser, 2009; Kudryavtseva, 2000; Wittemyer and Getz, 2007). The established ethogram (Table 2.2) provides a list of social behaviors but does not distinguish which ones are agonistic. A hierarchy of the social behaviors was created in order to rank them from neutral to aggressive by referencing other published elephant ethograms. The numbers assigned to each level are strictly labels and have no analytical numeric value.

Table 2.3: Hierarchy of Social Behaviors. Modified from classifications of behaviors by Freeman et al. 2010, Hasenjager and Bergl 2015, Horback et al. 2012, and Wilson et al. 2006.

Level	Description	Behaviors
0	Neutral behaviors	Sentinel, Trunk to...
1	Less threatening, no contact	Approach, Avoid, Displace
2	No contact but still physically threatening	Charge, Ear Flap
3	Aggressive physical contact	Drive, Mount, Push, Spar, Strike

2.2.4 Incident During Data Collection

On 17 July 2018 Tara sustained an injury that affected the study. In order to evaluate the situation and to put Tara on barn-rest, the two elephants were separated from 18-23 July 2018. Beginning on 24 July the elephants were together during the day but were not housed together at night until 7 August. Tara's mobility was moderately restricted as a result of the injury for several weeks. This incident created the longest

period of separation between Tara and Kelly since 2003 when Kelly was diagnosed with leptospirosis and was quarantined for several months. It was decided that the period of data collection should be extended for this study to take advantage of this unanticipated social experiment to determine if their social behaviors or space usage changed after the week-long separation and the potential effects of this lack of physical contact on their relationship. Therefore, the data set has been broken up into "Before" and "After" sections.

2.3 Data Analysis

2.3.1 Treatment of Outliers

An atypical amount of social interactions between the two elephants occurred on 26 August. Until that point there was an average of 1.29 interactions per hour. On 26 August there were 16 interactions in 4 hr, or an average of 4 per hour. During the last twenty minutes of data collection alone five interactions were recorded. After talking to the elephant management team, it was discovered that a keeper had been present on the berm and completing their own observations. As previously mentioned, the elephants often displayed different behaviors in the presence of their care team when they could be seen from the outdoor exhibit space so the fourth hour was removed from the data set. It was decided that a make-up hour of data collection should be completed in order to replace the hour that was thrown out and the 3 hr from 26 August should be treated as outlier data points during analysis. Therefore, the After data presented will only contain the 27 hr that did not include the outlier data points.

2.3.2 Determining Dominance Structure

In this study the winner and loser of each social interaction was recorded, alternatively labeled as the "Initiator" and the "Recipient" here. The dominant individual was determined by comparing how frequently each individual elephant was considered the Initiator during social interactions. This frequency was calculated by dividing the number of times each elephant was the Initiator by the total number of observed social behaviors. The elephant with the higher frequency of being the Initiator was considered to be the dominant individual. Wittemyer and Getz (2007) argued that the recipient of an agonistic behavior in a wild elephant herd walks away from the initiator to show submissiveness and can be easily identified as the loser. Although the elephant care team currently views Kelly as the more dominant of the two elephants, it is important to scientifically verify this through observation because Kelly and Tara's dominance hierarchy has changed over time. Studies on other elephant herds also find that the most dominant individual in an elephant herd, or matriarch, tends to be the oldest and largest individual present (Freeman et al., 2004; Freeman et al., 2010; Vidya and Sukumar, 2005), neither of which are true of Kelly.

The average number of social interactions that occurred per hour and the standard deviation were calculated for the Before and After data sets using the "Standard Deviation Calculator" at *Calculator.net*. These calculations were completed to determine if the number of interactions per hour changed after Tara's incident. The number of behaviors at each level of the Hierarchy of Social Behaviors was divided by the total number of social behaviors. This was done to determine if the percentage of occurrence for any level of behavior changed after the two elephants were reunited post-separation.

2.3.3 Statistical Analyses

Questions 2 and 3 focus on patterns of behavior based on location within the exhibit. Observed patterns of spatial use were compared to random patterns of spatial use, with the spaces being corrected for amount of space covered by each area. For example, data indicating one elephant spent 20% of their time in Area X would be different if Area X took up 20% of the exhibit space versus 80%. Chi-Square tests were used to compare actual vs. expected (random) frequencies of spatial use. Approximations of the proportions of total area taken up by Areas 1 - 4, found in Table 2.4, were calculated by using measurements provided by the elephant management team and the Google Earth "Measure distance and area" function. The "One-Way Chi-Square 'Goodness of Fit' Test" by *VassarStats: Website for Statistical Computation* was utilized for all Chi-Square calculations.

Table 2.4: Size of Areas Within Outdoor Elephant Exhibit. Total area of outdoor elephant exhibit = 793 m^2.

Area Number	Size of Area (m^2)	Proportion of Total Exhibit
1	400	.504
2	204	.257
3	109	.137
4	81	.102

2.3.4 Patterns of Exhibit Spatial Use

Each visual scan recorded the location of both elephants regardless of which elephant was the focal individual. In order to analyze if the elephants displayed a pattern of exhibit spatial use, the number of times they spent in each area were summed and used as the observed frequency values in the Chi-Square tests. Tests were run for the conditions together versus separated and before versus after.

2.3.5 Patterns of Social Interaction Occurrence by Location

A list was made of all social interactions between the two individuals. The location of the focal individual was used as the location of the social interaction. A count of the location for all social interactions was taken, as well as the locations for only social interactions categorized as Levels 1-3. These were used as observed frequency values in the Chi-Square tests for the conditions all social interactions versus only agonistic interactions and before versus after incident.

Chapter 3. Results

3.1 Determining Dominance Structure

The Before data set contained 50.67 hours of observations and the After data set contained 27.00 hours of observations. There was a total of 62 social interactions observed in the Before portion of the data and 48 in the After portion. Kelly was the Initiator for all 110 interactions, making Tara the Recipient for all 110.

3.1.1 Social Interactions by Level on the Hierarchy of Social Behaviors

The Before data set had an average of 1.19 ± 1.24 interactions per hour. The After data set had an average of 1.41 ± 1.45 interactions per hour. The level of social behavior with the highest frequency in the Before data set was Level 1, followed by levels 2, 0, and 3, as seen in Table 3.1. In the After data set Level 1 was the most common level of social behavior, followed by levels 0, 3, and 2, found in Table 3.2. Compared to the Before data set, there was a lesser percentage of Level 1 and 2 interactions and a greater percentage of Level 0 and 3 interactions in the After data set.

Table 3.1: Number of Social Interactions in the Before Data Set.

Level	Count	%
0	5	8.1
1	49	79.0
2	6	9.7
3	2	3.2

Table 3.2: Number of Social Interactions in the After Data Set.

Level	Count	%
0	9	24.3
1	22	59.5
2	1	2.7
3	5	13.5

3.2 Patterns of Exhibit Spatial Use

3.2.1 Before Data Set

Both elephants had unique patterns of using the outdoor exhibit space when outside together. Exhibit use by Kelly was non-random with a p-value < 0.0001, χ^2 = 461.86, and df = 3, as seen in Table 3.3. Exhibit use by Tara was non-random with a p-value < 0.0001, χ^2 = 261.79, and df = 3, as seen in Table 3.4. The exhibit use patterns by each elephant were different from each other. Kelly used areas 3 and 4 more than randomly expected but used areas 2 and 3 more than Tara. Tara used areas 1 and 4 more than randomly expected and used the same areas more than Kelly. Area 2 was under-utilized by both elephants but Kelly used it more often than Tara. Area 4 was over-utilized by both but Tara used it more often than Kelly.

Table 3.3: Chi-Square Results for Kelly's Use of the Exhibit When Together with Tara in the Before Data Set. Kelly used areas 1 and 2 less than randomly expected and areas 3 and 4 more than randomly expected.

Area	1	2	3	4
Observed Frequency	1830	1088	1065	626
Percentage Deviation	-21.22	-8.15	68.66	33.16
Standardized Residuals	-10.23	-2.8	17.25	7.19

p-value < 0.0001 $\chi^2 = 461.86$ df = 3

Table 3.4: Chi-Square Results for Tara's Use of the Exhibit When Together with Kelly in the Before Data Set. Tara used areas 2 and 3 less than randomly expected and areas 1 and 4 more than randomly expected.

Area	1	2	3	4
Observed Frequency	2693	981	610	810
Percentage Deviation	4.89	-25.07	-12.59	55.89
Standardized Residuals	2.48	-9.07	-3.33	12.74

p-value < 0.0001 $\chi^2 = 261.79$ df = 3

When separated, the elephants changed their space-use patterns compared to how they used the exhibit when outside together. Exhibit use by Kelly was non-random with a p-value < 0.0001, $\chi^2 = 95.41$, and df = 3, as seen in Table 3.5. Exhibit use by Tara was non-random with a p-value < 0.0001, $\chi^2 = 1054.78$, and df = 3, as seen in Table 3.6. While separated, both individuals showed similar patterns of space use, using Area 3 more than randomly expected and used areas 1, 2, and 4 less than randomly expected.

Table 3.5: Chi-Square Results for Kelly's Use of the Exhibit When Separated from Tara in the Before Data Set. Kelly used areas 1, 2, and 4 less than randomly expected and Area 3 more than randomly expected.

Area	1	2	3	4
Observed Frequency	79	61	83	15
Percentage Deviation	-34.14	-0.28	154.52	-38.22
Standardized Residuals	-3.74	-0.02	8.82	-1.88

p-value < 0.0001 $\chi^2 = 95.41$ df = 3

Table 3.6: Chi-Square Results for Tara's Use of the Exhibit When Separated from Kelly in the Before Data Set. Tara used areas 1, 2, and 4 less than randomly expected and Area 3 more than randomly expected.

Area	1	2	3	4
Observed Frequency	44	39	248	0
Percentage Deviation	-73.62	-54.16	446.86	-100.00
Standardized Residuals	-9.51	-4.99	30.09	-5.81

p-value < 0.0001 $\chi^2 = 1054.78$ df = 3

3.2.2 After Data Set

Both elephants had unique patterns of using the outdoor exhibit space when outside together. Exhibit use by Kelly was non-random with a p-value < 0.0001, χ^2 = 440.68, and df = 3, as seen in Table 3.7. Exhibit use by Tara was non-random with a p-value < 0.0001, χ^2 = 1140.43, and df = 3, as seen in Table 3.8. Kelly used Area 3 more than randomly expected and used areas 2 and 3 more than Tara. Tara used Area 4 more than randomly expected and used areas 1 and 4 more than Kelly.

Table 3.7: Chi-Square Results for Kelly's Use of the Exhibit When Together with Tara in the After Data Set. Kelly used areas 1, 2 and 4 less than randomly expected and Area 3 more than randomly expected.

Area	1	2	3	4
Observed Frequency	1212	482	723	215
Percentage Deviation	-8.63	-28.74	100.51	-19.91
Standardized Residuals	-3.14	-7.48	19.09	-3.26

p-value < 0.0001 $\chi^2 = 440.68$ df = 3

Table 3.8: Chi-Square Results for Tara's Use of the Exhibit When Together with Kelly in the After Data Set. Tara used areas 1, 2, and 3 less than randomly expected and Area 4 more than randomly expected.

Area	1	2	3	4
Observed Frequency	1314	372	350	816
Percentage Deviation	-8.59	-49.25	-10.42	180.51
Standardized Residuals	-3.26	-13.33	-2.06	30.79

p-value < 0.0001 $\chi^2 = 1140.43$ df = 3

Changes were seen in the space use patterns of both individuals when the elephants were separated in the After data set. Exhibit use by Kelly was non-random with a p-value < 0.0001, $\chi^2 = 82.4$, and df = 3, as seen in Table 3.9. Exhibit use by Tara was non-random with a p-value < 0.0001, $\chi^2 = 64.97$, and df = 3, as seen in Table 3.10. Kelly used Area 3 more than randomly expected and did so more than when they were together. She also used areas 1, 2, and 4 less than when they were out in the exhibit at the same time. Tara changed her space use pattern to using areas 3 and 4 more than randomly expected as compared to just Area 4 when they were together. She used Area 4 less than when they were together but still used it more than randomly expected. Tara also used areas 1 and 2 less than when out in the exhibit along with Kelly.

Table 3.9: Chi-Square Results for Kelly's Use of the Exhibit When Separated from Tara in the After Data Set. Kelly used areas 1, 2, and 4 less than randomly expected and Area 3 more than randomly expected.

Area	1	2	3	4
Observed Frequency	63	16	52	2
Percentage Deviation	-6.01	-53.19	185.40	-85.26
Standardized Residuals	-0.49	-3.11	7.91	-3.14

p-value < 0.0001 $\chi^2 = 82.4$ df = 3

Table 3.10: Chi-Square Results for Tara's Use of the Exhibit When Separated from Kelly in the After Data Set. Tara used areas 1 and 2 less than randomly expected and areas 3 and 4 more than randomly expected.

Area	1	2	3	4
Observed Frequency	22	1	28	8
Percentage Deviation	-26.03	-93.4	246.53	32.89
Standardized Residuals	-1.42	-3.64	7.01	0.81

p-value < 0.0001 $\chi^2 = 64.97$ df = 3

3.3 Patterns of Social Interaction Occurrence by Location

3.3.1 Before Data Set

There were 62 total social interactions between the two elephants before the incident. Five were neutral and ranked as Level 0 on the Hierarchy of Social Behaviors scale while the other 57 were classified as agonistic behaviors. Occurrence of all social interactions by area was random and had a p-value = 0.7363, $\chi^2 = 1.27$, and df = 3, as seen in Table 3.11. Occurrence of agonistic social interactions by area was random and had a p-value = 0.8542, $\chi^2 = 0.78$, and df = 3, as seen in Table 3.12.

Table 3.11: Chi-Square Results for All Social Interactions by Area in the Before Data Set. Areas 2 and 4 had less interactions than would be randomly expected and areas 1 and 3 had more than would be randomly expected, but these results were not significant.

Area	1	2	3	4
Observed Frequency	32	14	11	5
Percentage Deviation	2.4	-12.12	29.56	-20.89
Standardized Residuals	0.13	-0.48	0.86	-0.53

p-value = 0.7363 $\chi^2 = 1.27$ df = 3

Table 3.12: Chi-Square Results for Agonistic Social Interactions by Area in the Before Data Set. Areas 1, 2, and 4 had less interactions than would be randomly expected and Area 3 had more than would be randomly expected, but these results were not significant.

Area	1	2	3	4
Observed Frequency	28	14	10	5
Percentage Deviation	-2.54	-4.44	28.04	-13.94
Standardized Residuals	-0.14	-0.17	0.78	-0.34

p-value = 0.8542 $\chi^2 = 0.78$ df = 3

3.3.2 After Data Set

There were 48 total social interactions after the incident. Ten were neutral and ranked as Level 0 on the Hierarchy of Social Behaviors scale while the other 38 were classified as agonistic behaviors. Occurrence of all social interactions by area was non-random and had a p-value = 0.0116, χ^2 = 11.03, and df = 3, as seen in Table 3.13. Area 3 had more social interactions than would be randomly expected. Occurrence of agonistic social interactions by area was non-random and had a p-value = 0.1255, χ^2 = 5.73, and df = 3, as seen in Table 3.14.

Table 3.13: Chi-Square Results for All Social Interactions by Area in the After Data Set. Areas 1, 2, and 4 had less interactions than would be randomly expected and Area 3 had more than would be randomly expected.

Area	1	2	3	4
Observed Frequency	14	8	12	3
Percentage Deviation	-24.93	-15.88	136.69	-20.42
Standardized Residuals	-1.08	-0.49	3.08	-0.40

p-value = 0.0116 $\chi^2 = 11.03$ df = 3

Table 3.14: Chi-Square Results for Agonistic Social Interactions by Area in the After Data Set. Areas 1 and 2 had less interactions than would be randomly expected and areas 3 and 4 had more than would be randomly expected, but these results were not significant.

Area	1	2	3	4
Observed Frequency	10	7	8	3
Percentage Deviation	-29.13	-2.78	108.33	4.9
Standardized Residuals	-1.09	-0.07	2.12	0.08

p-value = 0.1255 $\chi^2 = 5.73$ df = 3

Chapter 4. Discussion

4.1 Determining Dominance Structure

Results matched anecdotal evidence that claimed Kelly was the more dominant of the two elephants. Kelly initiated every observed social interaction over the course of the study. The frequency of social interactions per hour and the frequency of behaviors at each level of social behavior hierarchy experienced change after the elephants were reunited post-incident. More social interactions occurred per hour in the After data set, showing that Kelly was asserting her dominance more often once they were reunited. The most common level of behavior in both the Before and After data sets was Level 1, which consisted of Kelly approaching Tara by moving to within one body length of her or Tara moving away from Kelly's approach via avoid or displace behaviors. These mild behaviors assert Kelly's dominance without aggressiveness simply by making Tara move out of Kelly's way. The frequency of neutral Level 0 behaviors and severe Level 3 behaviors increased after their separation. Touch is an important form of communication and bonding for members of elephant herds (Vidya and Sukumar, 2005; Bradshaw, 2004; Freeman et al., 2010). The increase seen from the baseline Before data set suggests that Kelly may have been trying to get reacquainted with Tara after being apart for so long without physical contact. Elephants also have an acute sense of smell (Bagley et al., 2006; Bates et al., 2007) so there is a possibility that Kelly may have been smelling healing processes happening in Tara's body as well. The increase in frequency of the most severe social behaviors was a surprising result. Kelly asserted her dominance over Tara after Dottie's death by increasing the amount of aggressive behaviors she displayed

towards Tara. Their separation and lack of physical contact in July 2018 may have caused similar stressful conditions that led Kelly to reinforce her dominance over Tara in ways that had previously worked.

4.2 Patterns of Exhibit Spatial Use

4.2.1 Before Data Set

Both elephants had non-random patterns of space use when in the outdoor exhibit together and when they were the only elephant in the exhibit. When together, Kelly used areas 2 and 3 more than Tara. Her usage of Area 3 makes sense given that, as the more dominant individual, she has asserted her dominance in the past by controlling access to the barn. Area 3 also has shade, a water trough, and hanging enrichment items filled with hay and other types of food. In regards to Kelly's greater usage of Area 2, it is the sole entry point into Area 3 and therefore still restricts Tara's access to the indoor portion of the exhibit and the resources therein. These results are similar to those found in Leighty et al. (2010) where the more dominant females of the elephant herd controlled narrow, restricted areas of the outdoor exhibit space and spent more time at permanent shade structures compared to the less dominant individuals. However, the results in this study may be confounded due to food, water, and shade resources being present in Area 3 which potentially makes it a high-value area. Due to Kelly's greater use of areas 2 and 3, Tara is seemingly left with Areas 1 and 4 to use more than Kelly. This pattern does not match what was found in the Leighty et al. (2010) study because Tara used a larger percentage of the outdoor exhibit than Kelly despite her lower position in the dominance hierarchy. Potential reasons for this could be that Kelly values areas 2 and 3 much higher

than areas 1 and 4 so Tara can do what she wants with the rest of the outdoor exhibit or Tara chooses to stay out of Kelly's way by spending more time in areas 1 and 4. Area 2 may have been underutilized by both elephants because there is no water resource, little shade, and typically there is a low amount of food available in this section. Area 4 was overutilized by both individuals, which may be a result of its small size combined with access to the pool for water, a moderate amount of shade for most of the day, and almost always having a hanging enrichment device containing hay. These differences in resources should be recognized by animal care teams and be addressed so that items are spread out and not easily dominated by a single individual.

Separating the elephants affected their space use patterns. Kelly spent more time in areas 2 and 3, which she already used more than the other sections when in the exhibit together with Tara. Due to a fairly regular daily schedule for the elephants, she may have been anticipating her turn to go inside by staying in the areas closest to the barn door. Tara's space use pattern changed from using areas 1 and 4 more to using Area 3 significantly more and drastically reducing her time spent in all other sections of the outdoor exhibit. Kelly's absence meant Tara could use the resources in Area 3 without interruption or retribution from Kelly. She could also have been anticipating her turn to go inside as well.

4.2.2 After Data Set

The space use patterns of both elephants when together in the outside exhibit in the After data set were similar to the Before data set but had slightly different proportions. Tara still used Area 1 than Kelly but Kelly almost dominated the area instead by using it in an almost equivalent amount. Tara held on to dominance of the area

by a small margin. Tara used Area 4 more than Kelly and used it much more than she had previously in the Before data set. Kelly continued to use areas 2 and 3 more than Tara when together and her use of Area 3 was higher compared to the Before data set. These After data set results more closely match those found in the Leighty el al. (2010) study. Kelly almost dominated use of Area 1 in addition to areas 2 and 3, which would have greatly increased the amount of the outdoor exhibit space she used while maintaining her domination of restricted access areas. These changes may reflect Kelly re-establishing her dominance over Tara by restricting her into the smallest area of the outdoor exhibit and the one furthest from the barn. Tara may also have chosen to stay in Area 4 more often because it contained food, water, and shade in a small area in order to not have to move around as much while also staying away from the areas Kelly dominated.

Kelly's pattern of space use when in the outside exhibit alone was similar to that of the Before data set, using Area 3 more than the other sections and using it more than when she and Tara were together. Tara's pattern of space use when separated was different from when together with Kelly and changed to include using Area 3 in addition to Area 4 more than expected, which is similar to the Before data set. She may have continued to use Area 4 more than expected when separated because she may have been less willing to move from her position due to her injury even after Kelly was inside.

4.3 Patterns of Social Interaction Occurrence by Location

4.3.1 Before Data Set

Under the normal Before conditions the p-values for these Chi-Square tests were very high, meaning that there was no significant pattern to where social interactions occurred while Kelly and Tara were together outside. This was not expected given that

both elephants had significant patterns in where they chose to spend their time in the exhibit. This likely means that Kelly was indiscriminate about where she chose to exert her dominance over Tara.

4.3.2 After Data Set

Once the elephants were reunited after Tara's incident, the p-values of the Chi-Square tests decreased dramatically. The pattern of all social interactions was significant and the pattern for only agonistic interactions was lower than in the Before data set, but was not significant at the $\alpha = 0.05$ level. Social interactions occurred more than expected in Area 3 versus any other section of the outdoor exhibit space. This seems like a reflection of Kelly's past protective behaviors of the barn as described in Elgart (2015). The increase in social interactions in this area may also have encouraged Tara to stay far away from it by going to the opposite corner of the exhibit in Area 4. Tests for correlation between level of social interaction and location within the outdoor exhibit were not conducted because the number of incidences in some areas were too small to properly conduct Chi-Square tests.

4.4 Future Research

This project was intended to be included in a larger research project monitoring the behavior of the elephants before and after they move to a new complex. Given Kelly and Tara's history of social upheaval after stressful situations, moving to a new space and being joined by new herd members both have the potential to cause new disturbances in their social and solitary behaviors as well. The Before data set can be used as a reference for how they typically behave in the current exhibit. Observations should be repeated

once they move to determine if their behavioral patterns are similar or different in the new exhibit after they have time to adjust.

The unique situation that arose during this study leads to potential future research of its own. Significant differences were seen in how each elephant used the exhibit and in how they interacted with each other once they were reunited after a week-long separation. Observations could be repeated at regular intervals to see if their behavioral patterns return to the baseline levels seen in the Before data set and how long it takes to do so. These additional rounds of observations could also be helpful in determining if changes in seasons, weather conditions, and shade patterns in the exhibit have any effect on space use by the elephants.

4.5 Conclusions

1. Kelly is the more dominant individual of the two elephants at Zoo Atlanta and she displayed her dominance over Tara in more physically threatening ways once they were reunited after an extended separation.
2. Each elephant had her own significant patterns of space use within the outdoor exhibit which were affected by whether they were together versus separated and before versus after Tara's injury.
3. Social interactions did not correlate with specific areas of the exhibit under normal conditions but patterns began to arise when the elephants were reunited after Tara's injury.

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